Interrelationship and Path Coefficient Analysis among Yield and Yield Related Traits in Sesame (*Sesamum indicum* L.)

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Abstract: Pakistan is facing severe scarcity of edible oil and spending a huge amount of foreign exchange on its annual import. Sesame is the best option as an edible oilseed crop due to less water requirement. The present study was conducted to estimate the genetic variability and trait association among 13 sesame genotypes in research area of Oilseeds Research Institute (AARI), Faisalabad, Pakistan during the crop season 2014. The data were subjected to analysis of variance, correlation and path analysis. Analysis of variance showed that genotypes differed highly significantly from each other for all the characters. Plant height, branches per plant and capsules per plant showed high mean values. Yield per plant had highly significant positive correlation of all other traits both at genotypic and phenotypic level. Path analysis revealed that capsules per plant had highest direct effect on seed yield per plant and Seeds per capsules had highest indirect effect via capsules per plant on seed yield per plant. So the trait capsules per plant may be used as selection criteria for the improvement of seed yield of sesame.

1.   Introduction

Pakistan is facing an acute shortage of edible oil due to increase in demand and production gap. The indigenous edible production does not match with growing demand of population. Total availability of edible oil was 3.069 million tonnes as against the local production of 0.567 million tonnes, importing 2.502 million tonnes of edible oil worth US$ 2.50 billion during the year 2012-13 (Govt. of Pakistan, 2013-14). During year 2012-13, 29.10 thousand tons of sesame seed was produced in Pakistan from an area of 70.90 thousand hectares (Agricultural Statistics of Pakistan, 2012-13). During 2013-14, 37.63 million tons sesame seed worth Rs.7342 million was exported (Federal Bureau of Statistics, 2013-14).There is a need to reduce gap between demand and production of edible oil for the preservation of revenue.

Sesame (*Sesamum indicum* L.), a conventional oilseed crop from Pedaliaceae family (Ashri, 1998) and Tubeflorae order (Nayar, 1976), is grown well in tropical and subtropical areas of the world (Gandhi, 2009). There are branched and single stem varieties. Sesame plant bears deep root system and it is fine adapted to water deficit conditions. Areas with 350-600mm rainfall are well suited for its cultivation. The best range of temperature for growth blossoms and fruit ripening is 26-30⁰C. It is grown in various parts of the world on over 2.02 million hectares (20,000 km^2).

About 70% of the world's sesame crop is grown in Asia, while Africa grows 26% (Hansen, 2011).

Sesame is a short duration crop which completes its cycle within 100-110 days. It is fit as catch crop in Zaid Kharif, and wheat can be timely planted after sesame. Therefore, there is great scope of horizontal expansion of sesame without affecting current area under different crops. Sesame is a very rewarding crop due to its low cost of production and high price. (Anwar *et al*., 2013).

Sesame seed contains more than 50% oil and about 25% protein. Due to the presence of natural antioxidants like sesamin and sesamol it is considered as an excellent source of edible oil (Brar and Ahuja, 1979). Sesame seed also contains high percentage of some essential amino acids (Kanu *et al*., 2007a, b, 2009) and vitamin B complex, important for cell oxygenation influencing liver cells favorably (Sarwar and Hussain, 2010). The chemical composition of sesame seed shows that the seed is a good source of carbohydrate (13.5%), protein (18-25), ash (5%) (Borchani *et al*., 2010) and about 50% oil of high quality (Roy *et al*., 2009). Sesame seeds also possess the essential fatty acids (EFAs) such as linoleic acid and high lignin that comprises of sesaminol sesamin, sesamol and Sesamolinol (Katsuzaki *et al*., 1994). It is rich source of calcium, protein, vitamin E and contains a little amount of vitamin A, B_1 and B_2 (Morris, 2002).

As the demand of sesame utilization is increasing day by day therefore, it is necessary to make efforts for the development of high yielding sesame cultivars. The present study was designed for evaluation of sesame germplasm to study genetic variability and association among different yield related traits. This information may be useful to plan further for the development of high yielding hybrids and synthetics in sesame.

2.   Material and Methods
Experimental Conditions
The present investigation was carried out in the experimental area of the Oilseeds Research Institute, Faisalabad, Pakistan during the year 2014. Faisalabad has arid climatic conditions, lies between 31^0 - 26^0 N and 73^0 -60^0 E longitude with an elevation of 184 meters above sea level. The crop season for sesame is usually from June to November. Monthly average temperature for the year 2014 are shown in Figure below.

Experimental Material
The plant material for research consisted of 13 sesame genotypes presented in Table-1. These were developed and maintained by the Oilseeds Research Institute (AARI), Faisalabad, Pakistan.

Table 1. Sesame accessions used as research material

Sr. No.	Accessions	Type	Sr. No.	Accessions	Type
1	40009	Branched	8	50009	Branched
2	50007	Branched	9	87005	Branched
3	96020	Branched	10	86001	Branched
4	70002	Branched	11	TS-5	Branched
5	86003	Branched	12	96002	Erect
6	77011	Branched	13	TH-6	Erect
7	87006	Branched			

Fig: Monthly average min. and max. temperature during 2014
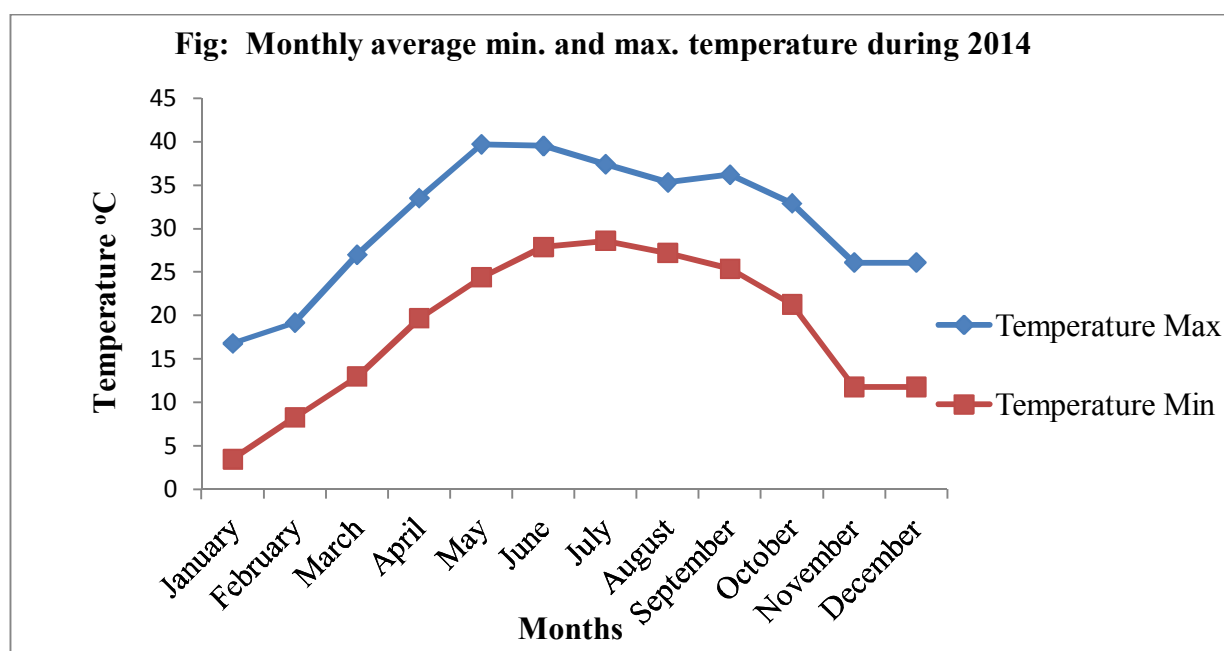
Source: Agricultural Meterology Cell, Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan.

Experimental Layout
Sesame accessions were sown in the field by using randomized complete block design (RCBD) with three replications. Three seeds were sown per hole, made with the help of dibbler and later thinning was practiced leaving only one plant per hole. Two rows of 5 m length each were used for each entry per replication. Row to row distance 45 cm and plant to plant distance 10 cm for erect types and 15 cm for branched types was maintained. One bag of urea/acre was applied at the time of sowing. Three irrigations were applied.

Data Recording

Observations were recorded on the following pre and post-harvest characteristics at maturity for 10 plants in each accession per replication.

Plant height (cm), branches per plant, pods per plant, seeds per pod, seed yield per plant (g) and 1000-seed weight (g).

Statistical Analysis

The data analysis of variance was performed on each measured trait as proposed by Steel and Torrie (1980). The heritability of a population is the proportion of observable differences between individuals that is due to genetic differences. Factors including genetic, environmental and random chance can all contribute to the variation between individuals in their observable characteristics. Thus heritability estimates were determined by the formula given by Falconer (1989). Genotypic (r_g) and phenotypic (r_p) correlation coefficients were determined as described by Kwon and Torrie (1964) whereas path coefficients analysis was made according to Dewey and Lu, 1959. In path coefficient analysis relationship between variables in multivariable system is considered. Therefore, in the present investigation, path coefficient analysis was carried out by taking seed yield per plant (g) as dependent variable and other observed traits as independent variables.

3.   Results and Discussion

Correlation analysis

Correlation analysis figure out the intensity of relationship between two traits. For the present breeding material genotypic and phenotypic correlation were computed among the yield and yield components and are presented in Table-2. The critical examination of this table showed that the genotypic correlations for different traits under study were in general higher than respective phenotypic ones, indicating there by an association among the traits under study due to genetic factors rather than environmental effects in all the genotypes.

Plant height:

The Table-2 revealed that the plant height had positive significant correlations with capsules per plant, branches per plant and seed yield per plant at both genotypic and phenotypic level, whereas non significant correlation with seeds per capsules. Plant height had negative and non significant correlations with 1000-seed weight at both genotypic and phenotypic levels. Karuppaiyan and Ramasamy (2000), Bhuyan and Sarma (2004), Siddiqui *et al*. (2005), Mothilal (2005), Sumathi and Muralidharan (2010), Yol *et al*. (2010), Goudappagoudra *et al*. (2011) and Akbar *et al*. (2011) reported positive and significant correlation of plant height with seed yield/plant.

Table-2: Genotypic and phenotypic correlations for different traits in sesame

		CPP	BPP	SPC	1000SW	YPP
PH	r_g	0.573**	0.749**	0.078	-0.013	0.357*
	r_p	0.571**	0.746**	0.076	-0.015	0.355*
CPP	r_g		0.554**	0.653**	0.477**	0.917**
	r_p		0.553**	0.648**	0.474**	0.916**
BPP	r_g			0.146	0.035	0.414**
	r_p			0.146	0.033	0.414**
SPC	r_g				0.487**	0.749**
	r_p				0.480**	0.741**
1000SW	r_g					0.761**
	r_p					0.758**

**= highly significant

PH =Plant height, **CPP** = Capsules per plant**, BPP**= Branches per plant,   **SPC**= Seeds per capsule, **1000SW=** 1000 Seeds weight, **YPP=** Yield per plant.

Branches per plant

Branches per plant showed highly significant positive genotypic and phenotypic correlations with yield per plant, plant height and capsule per plant shown in Table-2. Arulmozhi *et al*. (2001), Bhuyan and Sarma (2004), Siddiqui *et al*. (2005), Mothilal (2005), Singh (2005), Yol *et al*. (2010) and Goudappagoudra *et al*. (2011) also reported positive and significant correlation of number of branches per plant with seed yield/plant.

Capsules per plant

Capsules per plant showed a highly significant positive genotypic and phenotypic correlations with plant height, branches per plant, seeds per capsule, 1000 seed weight and yield per plant shown in Table-2. Uzun and Cagrgan (2001), Arulmozhi *et al*. (2001), Bhuyan and Sarma (2004), Siddiqui *et al*. (2005), Mothilal (2005), Singh (2005), Yol *et al*. (2010), Vanishree *et al*. (2011), Goudappagoudra *et al*. (2011), Akbar *et al*. (2011), Vanishree *et al*. (2013) and Thirumala *et al*. (2013) also reported positive and significant correlation of number of capsules per plant with seed yield/plant.

Seeds per capsules

Table-2 indicated that seeds per capsules had positive and non significant genotypic correlations with plant height and branches per plant. There were positive and highly significant correlations between Yield per plant, capsules per plant, and 1000-seed weight. Singh (2005), Siddiqui *et al.* (2005), Parameshwarappa *et al*, (2009), Goudappagoudra *et al.* (2011) and Daniya *et al.* (2013) also reported positive and significant correlation of seeds per capsules with seed yield/plant.

1000-seed weight

A critical view of Table-2 made it obvious that 1000-seed weight had positive and highly significant correlations with yield per plant, capsules per plant and seeds per capsule both genotypic and phenotypic level. However branches per plant had a positive correlation with 1000-seed weight at genotypic level. Bhuyan and Sarma (2004), Mothilal (2005), Yol *et al.* (2010), Sumathi and Muralidharan (2010), Goudappagoudra *et al.* (2011) and Akbar *et al.* (2011) also reported positive and significant correlation of 1000-seed weight with seed yield/plant. Plant height showed a negative and non significant genotypic and phenotypic correlation with 1000 seed weight

Path Coefficient Analysis

Path coefficient is separation of correlation coefficients into components of direct and indirect effects. The use of methods needs a cause and effect situation among the variables and the researcher must assign direction in the casual system based upon experimental evidences.

The Table-3 presents the estimate of direct and indirect contribution of plant height, capsules per plant, branches per plant, seeds per capsules, 1000-seed weight, to seed yield.

Direct and indirect effects of plant height on yield per plant:

Table-3 showed that plant height had a negative direct effect on yield per plant (-0.0830). The indirect effects via capsules per plant, branches per plant and seeds per capsule were positive while via 1000-seed weight was negative. Capsules per plant had high indirect effect of plant height on yield per plant (0.3710).

Direct and indirect effects of branches per plant on yield per plant:

It was noticed from Table-3 that direct effect of branches per plant on yield per plant was positive (0.0849). Arulmozhi *et al.* (2001), Bhuyan and Sarma (2004), Gnanasekaran *et al*, (2008) and Kumar and Vivekanandan (2009) also reported positive direct effect of branches per plant on yield per plant. The indirect effects via capsules per plant, seeds per capsule and 1000-seed weight were positive while through plant height was negative. Capsules per plant had high indirect effect of branches per plant on yield per plant (0.3588).

Direct and indirect effects of capsules per plant on yield per plant

The direct effect of capsules per plant on yield per plant was positive (0.6480). Kavitha and Ramalingam (2000), Arulmozhi *et al.* (2001) Goudappagoudra *et al.* (2011), Vanishree *et al.* (2013) and Thirumala *et al.* (2013) reported positive direct effect of capsules per plant on yield per plant. The indirect effect via number of branches per plant, seeds per capsule and 1000-seed weight were positive while via plant height was negative shown in Table-3. 1000-seed weight had high indirect effect of capsules per plant on yield per plant (0.1830).

Direct and indirect effects of seeds per capsules on yield per plant:

Table-3 reflected that direct effect of the seeds per capsules on yield per plant was positive (0.1326). Siddiqui *et al.* (2005), Goudappagoudra *et al.* (2011), Ibrahim and Khidir (2012) and Daniya *et al.* (2013) reported positive direct effect of seeds per capsule on yield per plant. The indirect effect via capsules per plant, branches per plant and 1000-seed weight were positive while through plant height was negative. Capsules per plant had high indirect effect on yield per plant (0.4232).

Direct and indirect effects of 1000-Seed weight on yield per plant:

Table-3 revealed that direct effect of 1000-seed weight on yield per plant was positive (0.3837). Arulmozhi *et al.* (2001), Vanishree *et al*. (2011), Goudappagoudra *et al.* (2011) and Ibrahim and Khidir (2012) also reported positive direct effect of 1000-seed weight on yield per plant. The indirect effects via plant height, capsules per plant, branches per plant and seeds per capsules were positive. Capsules per plant had high indirect effect on yield per plant (0.3087).

Table-3: Direct and indirect effects of different plant characters on seed yield per plant

| | Indirect effects | | | | | Direct effect |
	PH	CPP	BPP	1000SW	SPC	
PH		0.3710	0.0635	-0.0051	0.0102	-0.0830
CPP	-0.048		0.047	0.183	0.087	0.6480
BPP	-0.0621	0.3588		0.0133	0.0193	0.0849
1000SW	0.0011	0.3087	0.0029		0.0645	0.3837
SPC	-0.0064	0.4232	0.0123	0.1867		0.1326

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